From language to neurons, back and forth

Short introduction of my academic track

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Sapienza → Max Planck for Psycholinguistics

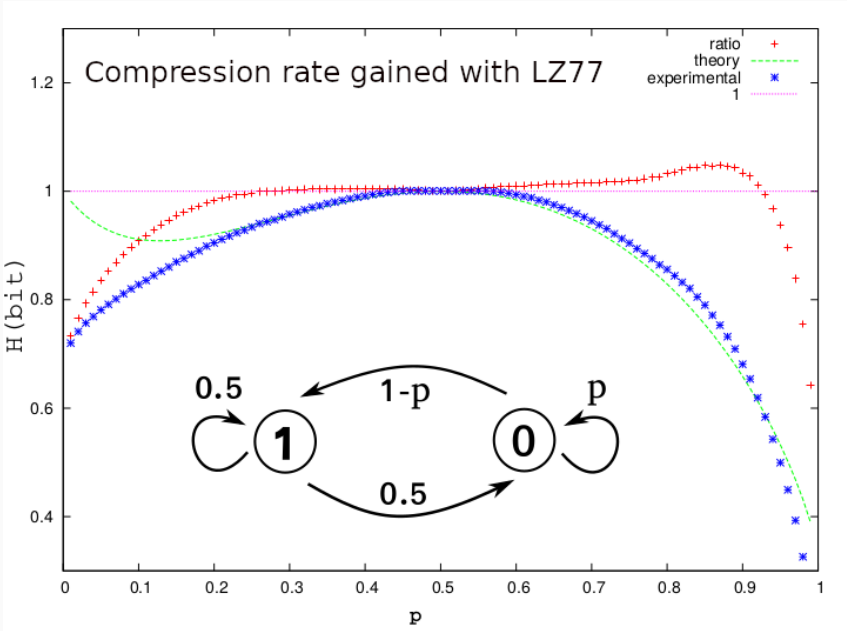
Entropy measures with LZ77 algorithm for correlated strings and literature texts

- BSc thesis in Physics in 2015 with V. Loreto: a project on language dynamics in the perspective of complexity theory.
- Study of literature texts as they were generated by Markovian sources
- Analysis of their *typical set* of substrings, with Asymptotic Equipartition Property.

$$
\begin{aligned}
H_{n+1} &= -\sum_{s_{n+1}} p(s_{n+1}) \ln p(s_{n+1}) \\
&= -\sum_{s_n, s_{n+1}} p(s_n) p(s_{n+1}|s_n) \ln p(s_n) p(s_{n+1}|s_n) \\
&= H_n - \sum_{s_n} p(s_n) \sum_{s_{n+1}} p(s_{n+1}|s_n) \ln p(s_{n+1}|s_n) = H_n + H(n+1|n)
\end{aligned}
$$

$$
h_n \doteq H_{n+1} - H_n = H(n+1|n) \tag{1}
$$

Figure 1: Analysis of LZ77 performance over theoretical entropy rate



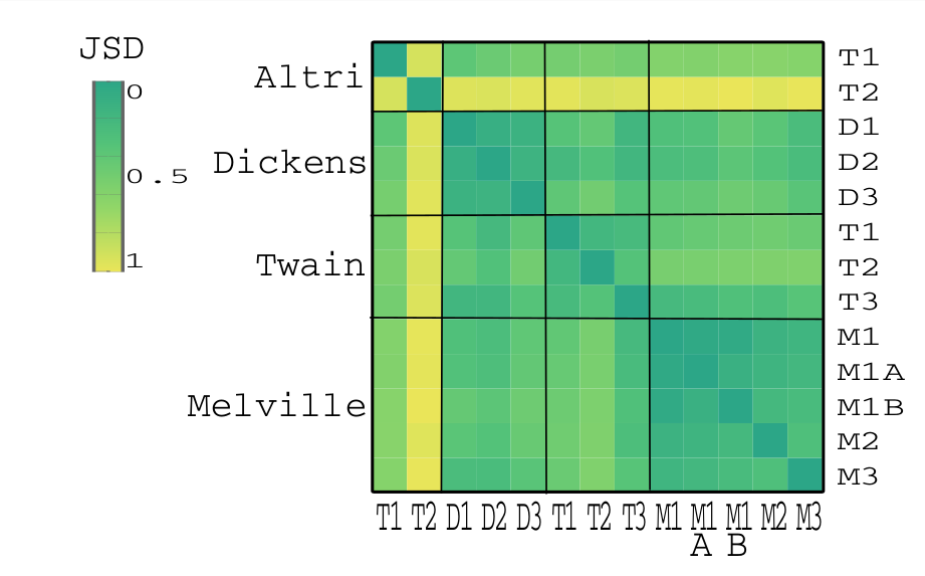
being $\mathcal{W}$ the **typical set**

$$AEP:$$

$$\lim_{N\to\infty} P(w \in \mathcal{W}) = 1$$

$$\lim_{N\to\infty} \#\mathcal{W} = \exp(hN)$$

Figure 2: Jenzen-Shannon divergence for word distribution:



$$JSD(P_a, Q_b) =$$

$$-\sum_a P(a)\ln(\frac{P(a)}{Q(a)})$$

$$-\sum_b Q(b)\ln(\frac{Q(b)}{P(b)})$$

DeNSE: Development of Neurons in Spatial Environments

- MSc in Paris Diderot as visiting student from Sapienza, Rome.
- **DeNSE**: efficient and parallel **simulator** for mechanistic modeling of neuronal outgrowth. Based on biophysical models.

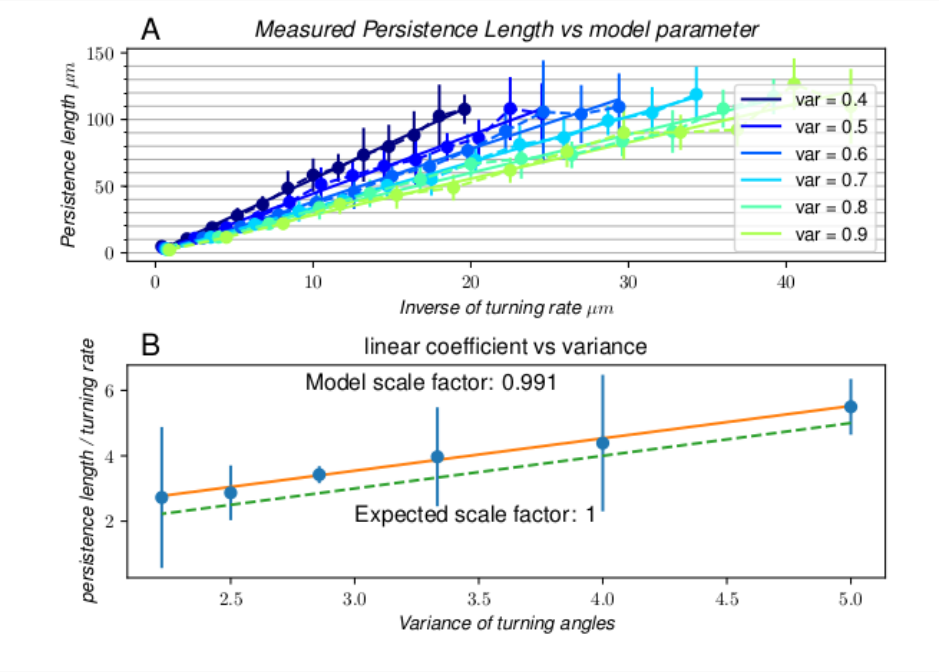


Figure 3: Growth Cone navigation: Run and Tumble

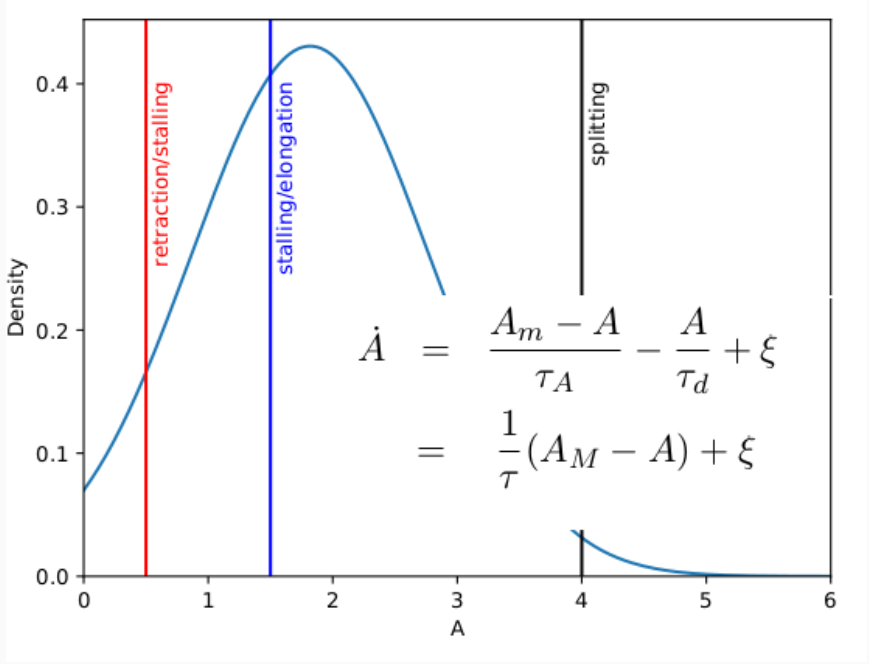


Figure 4: Neurite competition and pruning: Fokker-Planck

- DeNSE generates **biological plausible networks** for SNN simulators, i.e. *NEST*.
- Presents a new algorithm for **mechanical interaction** with confining environment

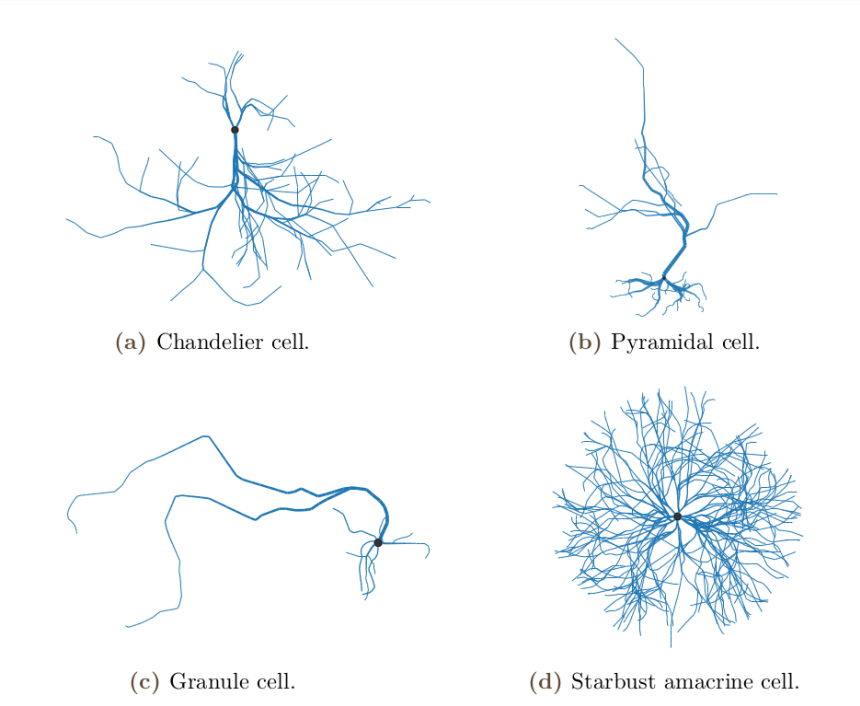


Figure 5: Biologically plausible neurons generated with DeNSE

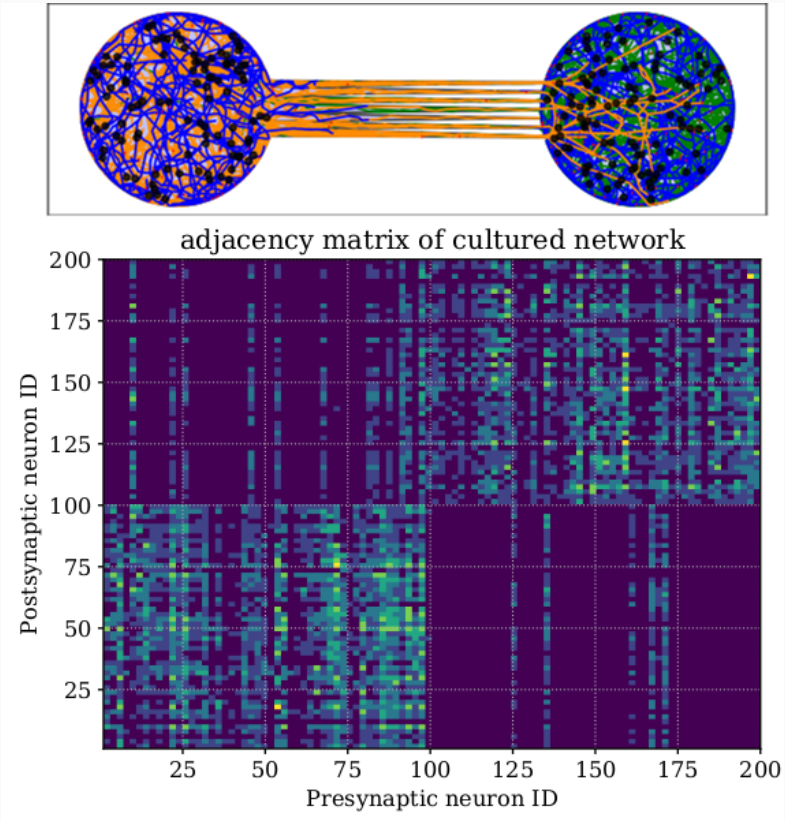
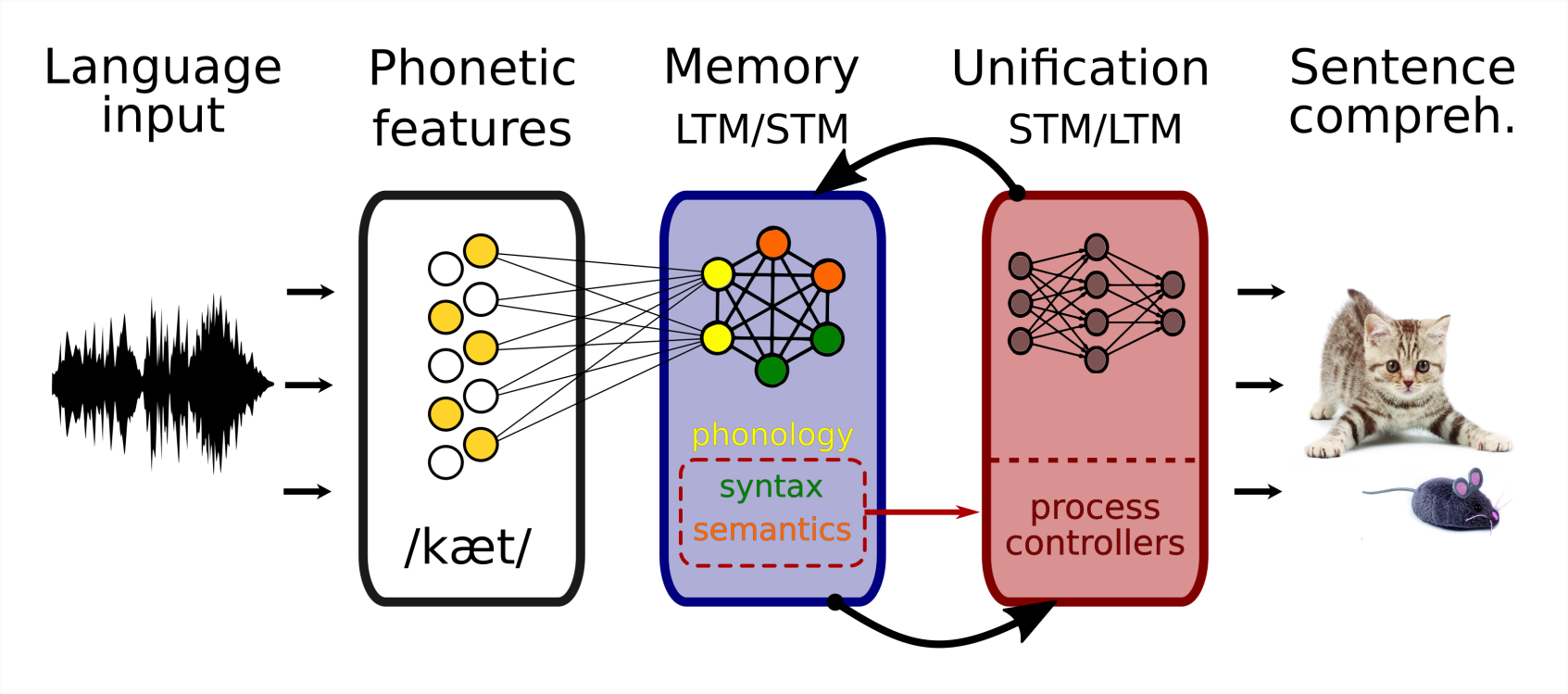


Figure 6: Simulated neurons in diode-like structure and their adjacency matrix

BQ1N PhD project

Task: Develop and validate a biological and mechanistic SNN model for Mental Lexicon.

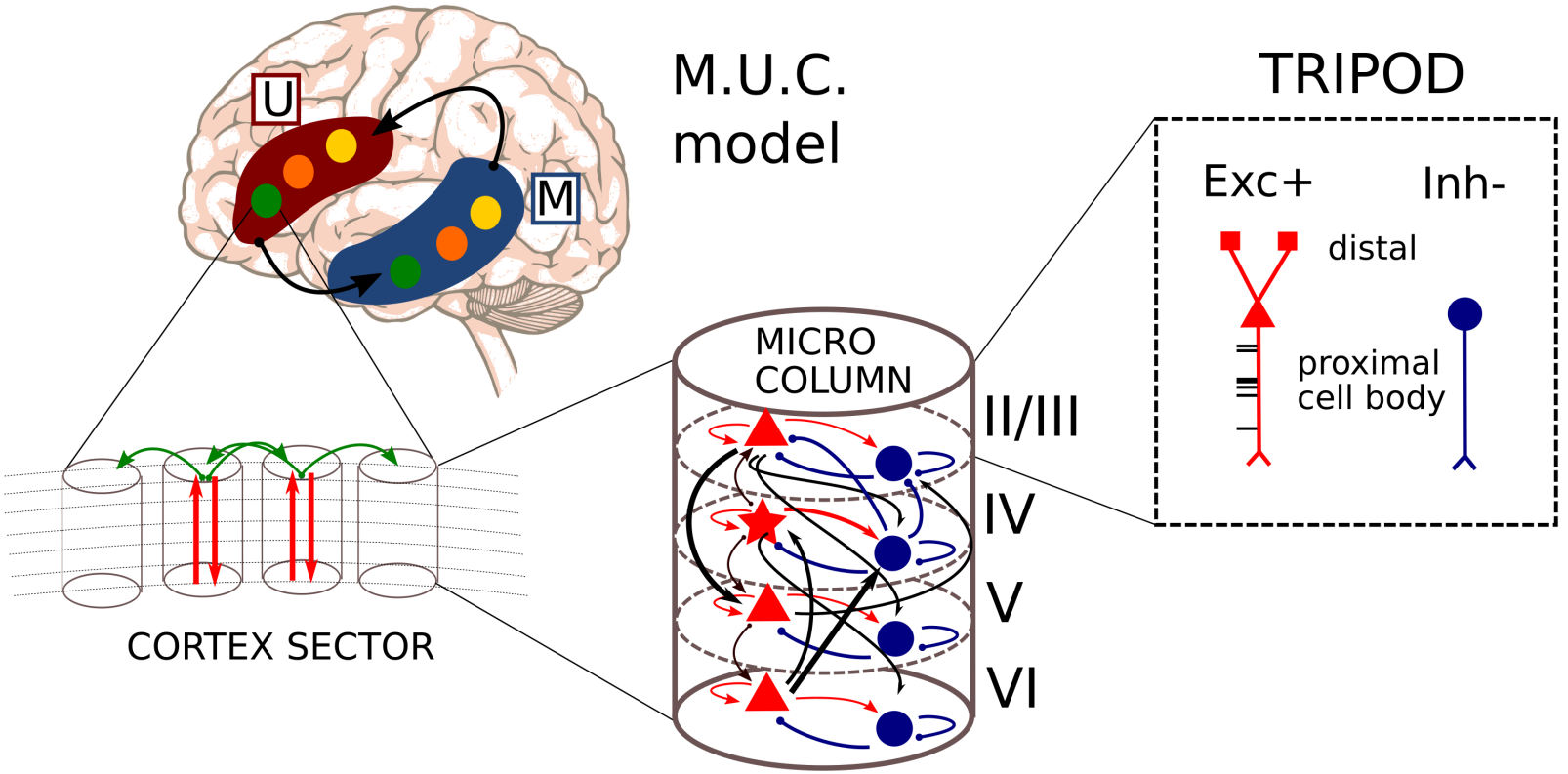
- Develop a neural model of the Mental Lexicon and combine with Unification network.
- Study the role of connectivity - over many scales - in memory formation and retrieval.



Structure interacting with adaptive processes

LTM/STM Learning process ⇄ Biological constraints

Network topology
Neuronal properties



Thank you for the attention